Technical Report

EVALUATION OF RADIO DATA SYSTEM - TRAFFIC MESSAGE CHANNEL AS A DYNAMIC DRIVER INFORMATION SYSTEM

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NOTICE

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EXECUTIVE SUMMARY

The motoring public experiences the effects of growing traffic congestion as increasing delays, accidents, and environmental pollution. One way that transportation engineers are seeking solutions to the problems of road congestion is by exploring alternative technologies within the framework of Transportation Systems Management (TSM) strategies. One of the strategies that has great potential for relieving congestion on road networks is the implementation of real-time information systems which, in a broad sense, is any combination of hardware and software that provides information to motorists during the course of their trip. The benefits provided from real-time traveler information can positively impact the operation of all transportation services and will lead to improvements in highway traffic operation and mobility as a whole.

The information provided to the motorist could be warning, regulatory or informative in nature and can be delivered in either a static or dynamic format. The major drawback of the static systems is their inability to adapt to changing traffic conditions. These factors, therefore, are addressed in the implementation of dynamic systems in which real, or almost real-time information is supplied to motorists during the course of their trip. Dynamic travel information can be provided through one of two methods:

- Individual in-vehicle information
- Roadside information

The information can be provided through the following alternative technologies:

- Radio Data Systems-Traffic Message Channel (RDS-TMC)
- Roadside Beacons
- Commercial Cellular Radio
- Mobile Data Radio

This report evaluates one of these alternative technologies, the RDS-TMC.

AN OVERVIEW OF RBDS/RDS-TMC

The Radio Data System (RDS), which is covered by the United States Radio Broadcast Data System (RBDS) Standard, was developed for Frequency Modulation (FM) by the European Broadcasting Union (EBU) and its member countries. It is a form of a data coding channel designed to operate in conjunction with commercial FM radio broadcasts.

One of the most important features of the RDS is the dedicated Traffic Message Channel (TMC) that will provide motorists with the latest traffic information by superimposing inaudible data on existing FM station carriers. The TMC is an additional feature of RBDS that is aimed at providing a better method for transmitting traffic information. The traffic information transmitted to motorists will trigger a display and/or speech synthesizer in the in-vehicle receiver. Incoming messages are stored in receiver memory and can be selected by the user according to travel corridor, area, or highway route numbers.

The RDS-TMC requires a special decoder and conventional radios cannot decode these signals without the added special decoder. The basic implementation allows a radio to indicate whether or not the tuned station broadcasts traffic information as part of its programming, and whether the tuned station is currently broadcasting a traffic message. This information could be used to stop a cassette or compact disk (CD) player and turn on the radio for the duration of the announcement. RDS radios typically allow the listener to use this information as a search criteria when scanning the band, stopping only on stations which broadcast traffic information.’

RDS has proven through numerous operational tests to be a robust system. Its parameters were chosen for minimum impact on the main channel operation of the radio station and for a low bit error rate. The RDS throughput or data rate is still low. The problem of low data rate may be ameliorated by using the Traffic Message Channel (TMC) feature or the high speed FM-SCA. The TMC feature is capable of multiplexing many RDS channels on various radio stations, each of which may be specific to a geographic region. This makes for more efficient utilization of the limited data capacity of the individual RDS channels.

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[1] *Small, E., Broadcast Subcarriers for IVHS: An Introduction, IVHS AMERICA. Washington, D.C. 1993.*

INFRASTRUCTURAL REQUIREMENTS AND COST

The implementation of RDS-TMC simply requires an agreement between the subcarrier operator and a radio station. There is no regulatory approval needed from any government agency. Additionally, since FM stations already exist, minimal capital investment will be required to get subcarriers on the air. It is estimated that the incremental cost of adding a subcarrier to a broadcast station is low, usually between four and six thousand dollars.[2] Furthermore, there is no license needed since the subcarrier is considered a subsidiary service of an existing broadcast licensee. The radio station does not even have to notify the Federal Communication Commission (FCC) that it is adding a subcarrier to its signal.[3] There are no regulations governing the use of broadcast subcarrier so long as the subcarrier is not used in support of an illegal activity.

While there are no significant infrastructural costs associated with the implementation of RDS-TMC, it does offer significant opportunities for the participation of the private sector. However, government involvement would be required to promote the concept and ensure the necessary levels of standardization and compatibility.[4]

PUBLIC/PRIVATE PARTNERSHIPS

In Europe, where the development of RDS-TMC is well ahead of the United States, there is still no full scale deployment of RDS-TMC even after numerous projects have successfully demonstrated the capabilities of RDS-TMC as a traffic management tool. Largely, the problems are institutional rather than technological. The technology for deploying RDS-TMC is available and the infrastructural costs are minimal; however, there are aspects of providing this service that go beyond the traditional boundaries of information dissemination by government agencies.

Private developers have invested a great deal of research time in developing the special in-vehicle decoders required to receive RDS-TMC and would expect to see some return on their investment. For these decoders to become marketable, there must be a source of information to feed them. Consequently, substantial investment is required either to instrument the road

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[2] ***Small, E., Broadcast Subcarriers for IVHS: An Introduction***

[3] ***Small, E., Broadcast Subcarriers for IVHS: An Introduction.***

[4] ***Davies, P., Applications of Advanced Technology to ease Traffic Congestion, STANDING COMMITTEE RESEARCH, American Association of State Highway & Transp. Off., Washington, DC., 1988.***

network or to obtain the information from private sources. At issue here is whether the consumers should pay for receiving this information in the convenience of their vehicles.

In addition, car manufacturers will require sufficient time to schedule the incorporation of these decoders into their vehicles and it is highly unlikely that car manufacturers will want to absorb the cost of outfitting vehicles with these decoders. At the same time, it is not certain that motorists will want to pay for a unit that will provide them with information that they receive free from many FM and/or AM radio stations. Therefore, the issue of who will be required to bear the cost of outfitting vehicles with the in-vehicle decoders must be resolved.

There is also the issue of the RDS-TMC competing for leasable broadcast space with the existing commercial subcarrier applications. The following will likely influence a radio station owner/broadcaster in choosing to lease a subcarrier:

- The revenue potential of the subcarrier
- The compatibility of the subcarrier with other commercial applications
- The public appeal of the subcarrier
- The legal and cost implications of leasing the subcarrier

In the final analysis, the RDS-TMC should have sufficient incentives for the broadcaster in order to compete favorably with other commercial applications. In general, it is not expected that a station will give up its existing profitable subcarrier in favor of ITS for less than market price.

The unresolved public/private partnership issues in the implementation of RDS-TMC is very evident in Europe. The private partnership involved in the development of the RDS-TMC have invested a great deal of research time and are expecting some return on their investment. However, the question of who should pay for providing the information is a problem that' operators in Europe are forced to grapple with as they race to implement RDS-TMC on a large scale.

A REVIEW OF CASE STUDIES

The application of RDS-TMC in particular, and subcarriers in general, for broadcasting travel messages has already been in practice in countries throughout Europe. In the United States, at least three states are involved in the operational testing of RDS-TMC: Texas, Minnesota, and Michigan. A summary of these European and US initiatives is presented in Table 1.

TABLE 1

A SUMMARY OF CASE STUDIES

PROJECT	[redacted]	[redacted]
The Autofahrer Rundfunk Information (ARI) system	Developed in West Germany in the early 1970s.	A simple tone-signaling system which requires a simple decoder. Traffic announcement carried as part of audio.
The Dutch RVI project.	Developed in the 1980s.	Integrated the TMC feature into RDS.
The West German BAST program.	Developed in the 1980s.	Integrated the ARI system with RDS-TMC.
European DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe) I & II program.	Operational testing since 1988.	Evolved the RDS-ALERT protocol and established standards in the RDS-TMC location coding, message content and message management acceptable throughout Europe. Also developed the Bearer Application Protocols (BAP).
Minnesota Department of Transportation's (MnDOT) TRILOGY project within the Twin Cities Metropolitan Area.	Project divided into three Phases: Phase I begun in early 1993; Phase II in late 1993; Phase III in 1994.	Installation and testing of basic RBDS capabilities on a FM station. Subsequent Phases are testing various types of receivers on a wider scale and have adapted the "Americanized" version of the RDS-ALERT protocol.

RDS-TMC IN THE I-95 CORRIDOR

A major drawback of RDS-TMC is that the technology is still in its infancy in the US. However, many successful projects in Europe have demonstrated the applicability of RDS-TMC as an information dissemination tool. It is believed that the opportunity exists for the use of HAR and RDS-TMC in tandem in the I-95 Corridor. In the eight metropolitan areas, where the unavailability of open AM frequencies already present a problem to HAR stations, the availability of existing FM stations that can carry the RDS-TMC signal favors the use of RDS-TMC.

In moving away from the metropolitan areas, frequencies on the AM band begin to open up making locations outside the metropolitan areas more suitable to HAR. Also, it will be difficult to at first to establish a comprehensive FM network across the corridor to carry RDS-TMC. Therefore, in the initial phases of RDS-TMC, HAR will still be required to disseminate information to motorists outside of the metropolitan areas.

RDS has also been shown to be effective in transmitting messages to a VMS.[5] This reduces the need for the installation of underground cables and the associated construction costs and also simplifies the location of remote signs. In addition, the messages to the VMS can also be transmitted to an in-vehicle decoder. Remote signposting, as it is referred to, can be used to transmit messages to remotely located VMSs in the Corridor.

The combined use of HAR, RDS-TMC, and VMS in the I-95 Corridor can provide motorists there with a comprehensive information dissemination system that will give them real-time, continuous, and consistent information. However, at this time, RDS-TMC is not immediately available for implementation in the Corridor. In addition to the institutional issues which must be resolved, the full-scale deployment of RDS-TMC in the US awaits the results of the Trilogy project in Minnesota, which will essentially shape the direction of the technology in the US. While the technology presents many advantages over HAR, particularly in the metropolitan areas, there are drawbacks in its development in the US that will delay its application in the I-95 Corridor.

In considering the implementation of RDS-TMC, the I-95 Corridor Coalition must give serious thought to the following:

- Full instrumentation will be needed on all main highways and alternate routes to provide reliable and real-time traffic information to the in-vehicle decoders.
- FHWA is heavily invested in the MnDOT Trilogy project and may not support another RDS-TMC project until the results of the Trilogy project are available.
- Developing a comprehensive network of FM stations across the I-95 Corridor to carry RDS-TMC will take time. Therefore, initially, RDS-TMC cannot be available for the whole corridor and must be used in tandem with other information dissemination devices.
- FM broadcasters must be involved in RDS-TMC from the beginning. At issue is how to make RDS-TMC profitable to the broadcasters without upsetting their listenership.

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[5] ***RDS: A Revolutionary Transmission System. D. E.P.I. Electronique.***

- The full participation of vehicle manufacturers must be enlisted to ensure their willingness to install the in-vehicle decoders.
- The I-95 Corridor Coalition cannot provide the RDS-TMC service on its own. Private partnerships are required to bring the service to motorists and there are obvious associated costs. A clear decision/policy is required on who will pay to cover those associated costs.

Without thorough consideration of these factors and definitive answers to the implied issues, the I-95 Northeast Corridor will not be ready for a full scale implementation of RDS-TMC. However, some initial answers to these issues can be obtained through a pilot project.

The next logical step will be to undertake a feasibility study specifically geared towards the implementation of the RBDS technology in the Corridor. A feasibility study is therefore proposed to evaluate the current traffic management structure with a view to implementing RBDS technology on a small scale within the Corridor. The study will address the following institutional issues:

- The distribution of FM stations in I-95 Corridor
- Programming structure
- Responsiveness of the FM station operators
- Responsiveness of the government traffic agencies
- Roles the governments are willing to play
- Responsiveness of operators and citizens
- Responsiveness of car manufacturers
- Legal issues
- Public/Private partnership participation
- The scale of the pilot project
- The cost evaluation of the pilot project
- Implementation and Evaluation of a Pilot Project

EVALUATION OF RADIO DATA SYSTEM-TRAFFIC MESSAGE CHANNEL TECHNOLOGY AS A DYNAMIC DRIVER INFORMATION SYSTEM

Traffic congestion is growing at an alarming rate that has adversely affected transportation in the United States. The reason for this growth is attributable to the growing demand in the use of the road network with the consequent ever increasing growth in traffic volume. Furthermore, it is impractical to accommodate traffic growth by the continuous physical expansion of the existing road network.

The motoring public experiences the resultant effects of this problem as increasing delays, accidents, and environmental pollution. One way that transportation engineers are seeking solutions to the problems of road congestion is by exploring alternative technologies within the framework of Transportation Systems Management (TSM) strategies. One of the strategies that has great potential for relieving congestion on road networks is the implementation of Dynamic Driver information System (DDIS) which is part of the ITS initiatives. DDIS is a traveler information system that can assist the traveler in choosing between the most appropriate services and travel routes. The benefits provided from real-time traveler information can positively impact the operation of all transportation services and will lead to improvements in highway traffic operation and mobility as a whole.

A driver information system, in a broad sense, is any combination of hardware and software that provides information to the driver during the course of his trip. The information could be warning, regulatory or informative in nature. Such a system delivery can also be either static in format, as in road signing and markings, or dynamic, as in Variable Message Signs (VMS) and Highway Advisory Radios (HAR). The major drawback of the static systems is their inability to adapt to changing traffic, road network, and environmental conditions. These factors, therefore, are addressed in the implementation of a DDIS with real, or almost real-time information supplied to the driver during the course of his trip. A typical DDIS can be used to warn drivers of various conditions including recurring congestion, unexpected delays caused by traffic incidents, or pre-planned activities such as highway construction and maintenance.

The implementation of a DDIS, which is part of the application of Advanced Transport Telematics (ATT), is promising new possibilities for dealing with the problems of congestion and incident management. ATT offers several options for transmitting and displaying dynamic travel information to the driver. These fall into two broad categories:

- Individual in-vehicle information
- Roadside information

The individual in-vehicle information can be provided through the following alternative technologies:

- Radio Data Systems-Traffic Message Channel (RDS-TMC)
- Roadside Beacons
- Commercial Cellular Radio
- Mobile Data Radio

In general, the structure of the dynamic in-vehicle information technologies requires the establishment of a central control center, a communications network, and the provision of a suitable in-vehicle unit. There are other types of transmission/communication media that are similar in structure with RDS-TMC:

- the high-speed FM Subsidiary Carrier Authorization (FM-SCA); and
- the FM multiplex broadcasting system which uses a digital modulation method called Level controlled Minimum Shift Keying (L-MSK); a multipath-proof system, developed in Japan, that is capable of a transmission rate of 16 bps.

This report, however,will evaluate one of these alternative technologies, the RDS-TMC.

AN OVERVIEW OF RBDS/RDS-TMC

DEFINITION OF RDS-TMC

The Radio Data System (RDS), which is covered by the United States Radio Broadcast Data System (RBDS) Standard, was developed for Frequency Modulation (FM) by the European Broadcasting Union (EBU) and its member countries. It is a form of a data coding channel designed to operate in conjunction with commercial FM radio broadcasts.

One of the most important features of the RDS is the Traffic Message Channel (TMC) which has the capability of superimposing inaudible data on existing FM station carriers. These data can then be selected for display or speech synthesis by in-vehicle decoders. RDS encoders are added to FM transmitters for the primary purposes of identifying radio broadcasts. These broadcasts can be subsequently decoded by receivers which, at the user option, can be self-tuning and capable of automatically selecting the strongest signal carrying a particular traffic program.

The TMC is an additional feature of RBDS that is aimed at providing a better method for transmitting traffic information. The purpose of a TMC is to continuously provide information to motorists using the RDS digitally-encoded, silent messages that will trigger a display and/or speech synthesizer in the in-vehicle receiver. The messages are language-independent; they can be decoded into the language of the user's choice through the capability of the RBDS Bearer Application Protocol (RBDS-BAP). Incoming messages are stored in receiver memory and can be selected by the user according to travel corridor, area, or highway route numbers. One of the most popular RDS features is the program service name that offers the listener a display of up to eight characters showing the call letters of the program being received.

This concept of using a subcarrier to convey additional information on Very High Frequency - Frequency Modulation (VHF-FM) broadcast has been in practice in the US since the mid-1960s. This usually involves FM stations using subcarriers to convey a subsidiary audio program signal. This "storecasting" was used to play background music in restaurants and shops." The effectiveness of the system lies in the fact that there is no crosstalk from the subcarrier into the main audio program.

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[6] ***RDS-ALERT CONSORTIUM. Review of Progress to Date on RDS-TMC, DRIVE V1029, Deliverable 1, June 1989.***

SYSTEM REQUIREMENT

The system requirement can be evaluated under the following categories:

- System Structure
- In-Vehicle receiver requirements
- Infrastructural requirements and cost

System Structure

RDS is intended for application to FM sound broadcasting transmitters in the 87.5-108.0 MHz range, which carry stereophonic (pilot-tone system) or monophonic sound broadcasts.[7] The data rate is 1187.5 baud divided into groups or sequences of 104 bits. Each sequence is made up of four blocks of 26 bits (see Figure 1). Each block of 26 bits comprises 16 data bits and 10 error correction bits or checkword.[8] An RDS group is the smallest package of data that can be defined within the system and it is broadcast using a 57 KHz subcarrier. This frequency is selected based on field results and it is divided by 48 to obtain the basic data rate of 1187.5 bits per second.

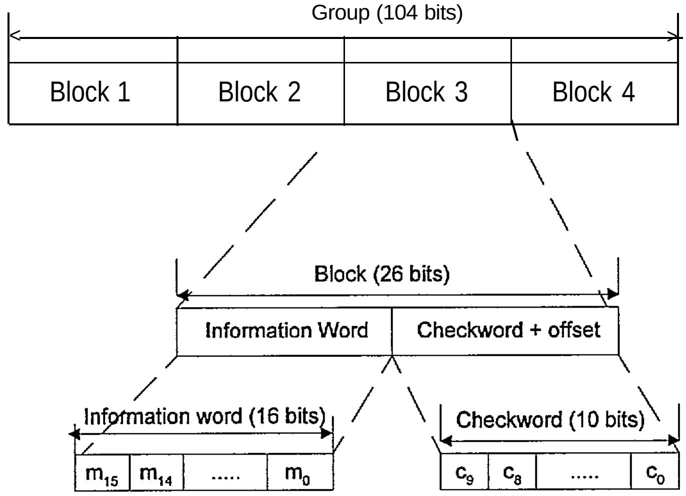

Figure 1. RDS group structure

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[7] *NATIONAL RADIO SYSTEMS COMMITTEE, UNITED STATES RBDS STANDARD, January 8, 1993.*

[8] *Davies, P., The Radio Data System-Traffic Channel, Conference Record of Papers presented at the First Vehicle Navigation & information Systems Conference, Toronto, Ontario, Canada (September 11, 13, 1989).*

The RDS-TMC has the capability of transmitting traffic information using "virtual language." Under this specification, the codes broadcast over-air comprise addresses of information stored in databases in the decoders. These databases contain look-up tables for coded values of different variables, plus lists of locations, including road or transit links. The processes involved in applications using this specification are as follows:'

- Before transmission, information is mapped into the virtual language by selection from look-up tables and location tables.
- The resulting coded messages are transmitted via RBDS, with frequent repetitions.
- In the receiver, codes received are translated back into user information using look-up tables, for use by the route guidance system or for presentation to the traveler.

The RDS-TMC requires an efficient coding system that ensures sufficient flexibility to deal with the full range of traffic situations. This issue has been addressed in various studies including the one prepared by Castle Rock Consultants (CRC). This resulted in the so-called CRC specifications or protocol.[10] The coding structure that deals with the allocation of bits within the RDS-TMC is designed to encode information on problem locations as well as other traffic messages. The coding requirements are briefly discussed below.

Location Coding

The RDS-TMC coding structure is designed to contain information on the problem site location within its message structure. Various location coding systems have been proposed but the CRC system seems to be the most efficient to date. In general, the goal of such a coding system is to be"

- comprehensive enough to ensure that all locations can be covered;
- flexible when dealing with current situations in different countries to allow the system to adapt to future changes; and
- efficient to enable the limited capacity of RDS-TMC to be used to best advantage.

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9 Proposal I for Trilogy High Speed RFP, Minnesota Department of Transportation, Minnesota Guidestar-intelligent Transportation Systems (ITS). August 15, 1995.

10 Castle Rock Consultants, Radio Data System (RDS) Traffic Message Channel (TMC). Final Report to the Commission of the European Communities, Nothingham, England, October, 1988.

11 Davies. P., The Radio Data System-Traffic Channel.

A typical location code, therefore, would contain information on the following:

- Geographic location of problem (Country, State, County, City)
- Name of highway or Route number
- Segment of highway or mileage number
- Point address that would help pinpoint the problem site
- Status Information (e.g., journey/link time, speed, delay, headway etc.)

The CRC protocol proposes reserving a standard 16-bit address for inter-urban networks as well as an extended location set bit for defining local places within the cities.

Message Coding

There are two possible types of message coding: single- and multi-sequence message coding. The single-sequence, which is considered more efficient, is designed to encode information on the following:

- message category (e.g., weather, traffic, alarm, etc.)
- specific instruction message (e.g., for diverting around a problem site)

The CRC protocol proposed a single-sequence of basic message texts using 11 bits, thereby giving over 2000 messages.[12]

The multi-sequence message structure carries, in addition to the information in the single-sequence, special infrequently broadcast messages. For example, common-sense advice messages are considered best coded in a second RDS sequence , as they will only be used occasionally. Multi-sequence message structure can also be used to carry optional, detailed message quantifiers, e.g., advisory speed limits, weight and width limits.

Every group of the RBDS data stream contains the Program Identifier (PI) code which occupies the first block of the group. Additional bits in every group are reserved for the group number (4 bits), the group letter (1 bit), the audio program type (5 bits) and the traffic program identification code (1 bit). The bits reserved for the group number enable 16 groups to be defined, the group

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[12] ***Davies, P., The Radio Data System-Traffic Channel.***

letter (A or B) doubles the number of groups, the program type allows for the categorization of program such as jazz, classical etc., the traffic identification code specifies if the station carries traffic information. The 64 bits of data per group minus the reserved data leave 37 bits of data per group. The groups as defined by the US RBDS standard are shown in Table 11.[13]

TABLE II

RBDS GROUP DEFINITION

GROUP TYPE		APPLICATIONS
DECIMAL VALUE	A AND B GROUPS	
0	Yes	Tuning and Switching Information
1	Yes	Program item number and slow labeling codes
2	Yes	Radiotext
3	No	LN-Location and Navigation
4	No	Clock time and date
5	Yes	Transparent data channels
6	Yes	In-house applications
7	No	Radio-paging
8	Yes	Reserved for Traffic Messaging - TMC
9	No	Emergency warning systems
10	No	Program type name
11		Undefined
12		Undefined
13		Undefined
14	Yes	Enhanced other networks information
15	Yes	Fast basic Tuning and switching information

Alert-C and Alert Plus Protocols[14]

The Alert-C protocol was developed to ensure a consistent use of the RBDS-TMC. The Alert (Advise and Problem Location for European Road Traffic) protocol, developed as part of the DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe) project defines the application for event driven driver information messages. This protocol defined a standard way for a traffic situation to be described. This includes the event, location, backup extent, expected duration and a diversion advise field.

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[13] *TRILOGY Operational Test, Concept/Preliminary Design Document, FHWA/MnDOT, May 1995*

[14] *TRILOGY Operational Test, Concept/Preliminary Design Document, FHWA/MnDOT, May 1995*

Although the Alert-C, which has been extensively tested in Europe, defines event driven driver information there is much more traffic and travel information to which travelers would like to have access. This information includes route guidance, transit, and parking. In response to this need, a variety of proposed additions are being made to the basic Alert-C to develop what is being referred to as Alert Plus.

The ITIS and RBDS-BAP

The International Traveler Information Interchange Standard (ITIS) is an open, non proprietary modular set of standards intended to serve the public interest by facilitating interconnection and interchangeability of traffic information systems, It provides for the implementation of the common travel information exchange standard on the RBDS bearer.

One of the hurdles to defining a standard format for traffic messaging is the restrictions inherent to the communication system being implemented. Because of these limitations on specific bearers (example bearer - RBDS) there was need to define a way of coding messages independent of the bearer. An ITIS document called the Bearer Independent Format (BIF) proposes such a standard. With a BIF developed, protocols for specific bearers can be developed. These specifications provide for application protocols on specific bearers and are called Bearer Application Protocols (BAP).[15]

The RBDS-BAP is a specification developed by the US Standard for digitally coded traffic and travel information. This specification was prepared by ENTERPRISE, a partnership of North American federal, state and provincial government entities; it specifies the application of basic ITIS functions on FM subcarriers using the RBDS coding. RBDS-BAP mainly covers the following:

- Driver information messages describing traffic situations.
- ITIS functions such as Route Guidance, parking and transit information.

The ITIS RBDS-BAP is a compilation of the latest version of Alert-C and the combination of documents that make up Alert Plus. The RBDS-BAP distinguishes between 5 types of data records:

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[15] ***TRILOGY Operational Test, Concept/Preliminary Design Document, FHWA/MnDOT, May 1995***

- Type 1: travel situations
- Type 2: route guidance information
- Type 3: additional travel situation descriptions
- Type 4: downloading of additional locations, not already pre-stored in receiver memory
- Type 5: transit schedules

The RBDS-BAP defines four subtypes of Type 1; travel situation data records, covering driver information (1A), general transit (1B), individual vehicle transit (1C) and parking information (1D). RBDS-BAP Type 2 data records provide for route guidance information. Link speed reductions is provided in the RBDS-BAP, since link speed reductions offer a highly bandwidth-efficient approach. Thus, Type 2 messages contain two basic items of information: the link location and the link speed reduction. Optionally, a prediction period can also be indicated for situations where short-term forecasting is in use.

Type 3 messages in the RBDS-BAP can be used to define phrases or full descriptions not included in the pre-defined Data Dictionary.

Type 4 messages permit downloading of new locations for travel situations or route guidance.

Finally, Type 5 messages provide for downloading transit schedules. The information specified in the BIF can be downloaded over the RBDS bearer.[16]

A typical RBDS-BAP descriptive coding for traffic and transit journey times, and link times/speeds (represented by “Journey time increase factor”) is given below.[17]

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[16] TRILOGY Operational Test, Concept/Preliminary Design Document, FHWA/MnDOT, May 1995

[17] International Traveler information Interchange Standard (ITIS) Radio Data System Bearer Application Protocol (RBDS-BAP), Part 2 (Version 2.5), June 1995.

RBDS-BAP Code	Traffic Description	Transit Description	Journey Time Factor [a]	Equivalent % Speed
0	no data available	no data available		
1	traffic stopped	very long delays	*>2000%*	*<5%*
2	stop and go traffic	long delays	*500-2000%*	*5-20%*
3	slow traffic	delays	*200-500%*	*20-50%*
4	heavy traffic	some delay	*125-200%*	*50-80%*
5	free flow	no delays	*100-125%*	*80-100%*
6	avoid	avoid		-
7	closed	closed	-	-

[a] Journey time increase factors indicate the ratio (expressed as a percentage) of the (current) mean journey time divided by the reference journey time.

Message Management

The RDS-TMC has outlined ways in which messages are handled by broadcasters and receivers. TMC messages are designed to be repetitive to help verify the validity of the received messages. The repeated messages are compared by the receiver for validity; and messages are accepted as valid only after they have been identically received several times. The system is also designed to prioritize messages according to currency and urgency status. A typical priority ranking scheme would be as follows:

- Highest priority, for immediate broadcast, interrupting existing RDS-TMC message cycles and being repeated very frequently;
- High priority, for non-delayed broadcasts through early insertion into RDS-TMC message cycles, with frequent repeats;
- Norma/priority, broadcast at intervals according to RDS-TMC channel capacity; and
- Background information, broadcast less frequently, when channel capacity permits,

The system provides for outdated message cancellation so that motorists are not misinformed. This would also help to ensure that TMC decoders do not fill up with irrelevant or superseded messages. Message cancellation can be achieved either through automatic cancellation by the receiver or by broadcasting cancellation messages.

In-Vehicle Receiver/Decoder Requirements

From the foregoing discussion, it can be seen that the RDS-TMC requires a special decoder. This is because RDS-TMC is a subcarrier that consists of ultrasonic signals above the range of human hearing. Moreover, conventional radios cannot decode these signals without the added special decoder. The basic implementation allows a radio to indicate whether or not the tuned station broadcasts traffic information as part of its programming, and whether the tuned station is currently broadcasting a traffic message. This information could be used to stop a cassette or CD and turn on the radio for the duration of the announcement. RDS radios typically allow the listener to use this information as a search criteria when scanning the band, stopping only on stations which broadcast traffic information.[18]

The RDS-TMC decoder is expected to have the following capabilities:

- Ensuring the validity of each received message;
- Checking if it has been received before;
- Determining the urgency; and
- Deleting messages which have become outdated.

Conceptually, there are three levels of urgency at a receiver functional level:[19]

- Extremely urgent, which will interrupt the radio or cassette on all equipped vehicles in the broadcasting region;
- Urgent, which will interrupt the radio or tape on vehicles which have selected the relevant route or area; and
- Normal, which will be made available on driver's request.

Although the receiver/decoder generally provides the user interface to the traveler information service, its functionality may vary substantially according to technical developments and market requirements. A virtual terminal model can be defined that covers a range of actual decoder functions:[20]

- simple decoders offering basic functions, with a limited locational database;
- more sophisticated decoders offering a full set of route guidance features and/or a wide range of location databases;

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[18] ***Small. E., Broadcast Subcarriers for IVHS: An Introduction, IVHS AMERICA, Washington, D.C. 1993.***

[19] ***Davies, P.. The Radio Data System-Traffic Channel.***

[20] ***Proposal for Trilogy High Speed RFP, Minnesota Department of Transportation.***

- decoders which monitor only a single, selected FM frequency, and others which employ more sophisticated search strategies of several or many channels;
- decoders which are active before the start of a trip, and others which must acquire their travel data after the trip begins;
- decoders which interface to in-vehicle route guidance equipment, and others which provide output via speech synthesis and/or visual displays;
- future decoders which will offer additional functions and services yet to be defined.

Infrastructural Requirements and Cost

The implementation of RDS-TMC simply requires an agreement between the subcarrier operator and a radio station. There is no regulatory approval needed from any government agency. Additionally, since FM stations already exist, minimal capital investment will be required to get subcarriers on the air. Furthermore, there is no license needed since the subcarrier is considered a subsidiary service of an existing broadcast licensee. The radio station does not even have to notify the Federal Communication Commission (FCC) that it is adding a subcarrier to its signal.[21]

There are no regulations governing the use of broadcast subcarrier so long as the subcarrier is not used in support of an illegal activity. An exception to this is in the case of non-commercial FM stations that must, if they use any subcarriers for any profit making activities, make an additional one available for use by radio reading services for the blind.

It is pertinent to mention that the effective application of RDS-TMC in alleviating recurring and non-recurring congestion problems in a given corridor will depend on, among other things, how well the road network in that corridor is developed. This means that the corridor should be capable of offering sufficient alternative routes or diversions at most of the locations susceptible to incidents or capacity reduction occur.

There is no significant cost associated with the implementation of RDS-TMC. Furthermore, there is very little cost associated with Research and Development (R&D) since much of the hardware needed to implement the system is already commercially available. It is estimated that the incremental cost of adding a subcarrier to a broadcast station is low, usually between four and

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[21] ***Small, E., Broadcast Subcarriers for IVHS: An Introduction.***

six thousand dollars.[22] The fact is that many companies manufacture the needed transmission equipment and all the major automobile receiver manufacturers offer vehicle radios with RDS features. Because RDS is a mass market system, several semiconductor manufacturers offer inexpensive integrated circuits to implement RDS.

The implementation of RDS in a metropolitan area would require low central investment levels, with the majority of the costs being borne directly by the system users. Infrastructural requirements would also be minimal, as RDS utilizes existing FM transmitters. These advantages will help the system overcome implementation barriers that might otherwise discourage public or private sector organizations from involvement in a new traffic information system. There are significant opportunities for the participation of the private sector . However, government involvement would be required to promote the concept and ensure the necessary levels of standardization and compatibility.[23]

There is also the issue of the RDS-TMC competing for leasable broadcast space with the existing commercial subcarrier applications. The following factors that will likely influence a radio station owner/broadcaster in choosing to lease a subcarrier:

- The revenue potential of the subcarrier.
- The compatibility of the subcarrier with other applications important to the broadcaster.
- The public appeal of the subcarrier.
- The legal and cost implications of leasing the subcarrier.

In the final analysis, the RDS-TMC should have sufficient incentives for the broadcaster in order to compete favorably with other commercial applications. In general, it is not expected that a station will give up its existing profitable subcarrier in favor of ITS for less than market price.

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22 Small, E., Broadcast Subcarriers for IVHS: An Introduction

23 Davies, P., Applications of Advanced Technology to ease Traffic Congestion, STANDING COMMITTEE RESEARCH, American Association of State Highway & Transp. Off., Washington, D.C., 1988.

SYSTEM COMPATIBILITY/ADAPTABILITY

An important factor to be considered in the implementation of a subcarrier is its impact on the entire broadcast system. In order to be viable, a broadcast subcarrier must operate without any interference to the reception of the regular broadcast of the host radio. This is not a trivial requirement in light of the vast range of receivers in use by the general public. It is not enough for the subcarrier user to be able to say to the broadcaster that the subcarrier transmission is "clean."[24] The assurance must be that in no class of receiver does the subcarrier generate any kind of spurious signal that would annoy the general public.

RDS has proven through numerous operational tests to be a robust system. Its parameters were chosen for minimum impact on the main channel operation of the radio station and for a low bit error rate. The implementation or adaptation of subcarrier technology on AM radio is not as advanced as in FM radio, but it is still a viable option. The problem with AM radio, however, lies in the fact that the occupied bandwidth of its broadcast is much less than what is on an FM station: 15 KHz as opposed to 240 KHz. There is no spectral room for a high speed "ultrasonic" data channel on an AM carrier. Implementation of a subcarrier on AM radio will require a subsonic transmission which is below the 20 to 30 Hz cutoff for human perception of low frequencies. Such low frequency operation limits the data rate possible with AM subcarriers to typically less than 100 bits per second.

This compatibility problem is usually not an important issue since the FM stations continue to have strong dominance over AM stations.[25] It appears that more people tend to listen to FM stations than to AM stations, not only because of the former's stereophonic feature, but also because FM stations broadcast more music than the latter. In any case, RDS-TMC can be operated in tandem with the existing AM radio broadcasts without any interference.

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[24] Paffenbarger, J. H., Optimized Implementation of SCA Subcarriers for Minimum Degradation of FM Stereo Reception, Proceedings: 4 1st Annual Broadcast Engineering Conference; 1987, National Association of Broadcasters, Washington, D.C.

[25] Small, E., Broadcast Subcarriers for IVHS: An Introduction.

A REVIEW OF CASE STUDIES

The application of RDS-TMC in particular, and subcarriers in general, for broadcasting travel messages has already been in practice in countries throughout Europe. A few of these European initiatives deserve brief mention. The Autofahrer Rundfunk Information (ARI) system was developed in West Germany in the early 1970s. ARI is a relatively simple tone-signaling system which requires only a simple decoder. It indicates which programs carry traffic announcements as part of the audio, when a traffic announcement is being broadcast, and the geographical area to which the announcement applies.[26] The European efforts to develop a subcarrier for FM radio culminated in the RDS specification in 1984. Soon after that several proposals were made to integrate the TMC feature into RDS. Such proposals include the Dutch RVI project, the Blaupunkt and the West German Ministry of Transportation (BAST) initiatives on coding structure using the ARI system.

The actual operational testing of the RDS-TMC system did not begin until the development of RDS-TMC protocol in 1988 by the Castle Rock Consultants (CRC) under the auspices of the Commission of the European Communities. Since then, several operational tests have been carried out in Europe under the framework of the European Community's DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe) program. Such projects include the RDS-ALERT (Advice and Problem Location for European Road Traffic) within DRIVE I.

RDS-ALERT sought to establish standards in RDS-TMC location coding, message content, and message management acceptable throughout Europe. DRIVE II was a logical follow-up which focused on the field trials of the various technologies. In particular, the ATT-ALERT and INTERCHANGE research and development projects are both dedicated to evolving an International Traveler Information Interchange Standard (ITIS) and Bearer Application protocols (BAP) in order to identify how existing messaging protocols can be mapped onto particular bearers. This can then be expanded to cover areas such as route guidance, parking, and transit information.

In the United States, at least three states are involved in the operational testing of RDS-TMC: Texas, Minnesota, and Michigan. It is estimated that more than 239 stations in the United States

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26 Davies, P.. and Klein, G.. field Trials and Evaluations of Radio Data System Traffic Message Channel, Transportation Research Record No. 1324, Transportation Research Board, National Research Council, Washington D.C., 1991.

are currently broadcasting RBDS. In Orange County, Texas, RBDS is currently being broadcast, and the County has based it's emergency preparedness and notification system on the service. To this end, it is estimated that more than 50,000 RBDS capable receivers have been sold[27]. The other projects are the Minnesota's Trilogy Pilot Project and Michigan's D.I.R.E.C.T[28] (Driver Information Radio utilizing Experimental Communication Technologies) projects. The Minnesota project will be discussed here.

THE TRILOGY PROJECT[29]

The Minnesota Department of Transportation (MnDOT), which has a 20-year history of providing traffic information to the Twin City Metro Area motorists as part of a comprehensive transportation system management program, has embarked on a small scale field testing of RBDS-TMC under the Trilogy Pilot program. The Trilogy project was started as part of a larger ITS program called Guidestar. This project created the procedures and established the infrastructure to utilize RBDS-TMC technology to broadcast traffic information. Prior to the Trilogy project, the MnDOT's Traffic Management Center (TMC) was already implementing motorist information programs aimed at distributing traffic information via variable message signs (VMS), a highway advisory radio service (HAR), and a cable network. These media, however, lacked the ability for motorists to selectively receive information of interest for their specific trip.

The Trilogy project has been divided into three principal phases. Phase I, begun in early 1993, involved the installation and testing of basic RBDS capabilities on a FM radio station sideband; and integration with the existing highway advisory radio service. In the pilot test ten receivers, manufactured by Delco Electronics, were evaluated, seven of which were installed into MnDOT fleet vehicles.

Phase II, begun in late 1993, comprised local RBDS-TMC test with 13 prototype receivers. There were eight Volvo units, six of which were installed in-vehicle and the remaining were laboratory tested. Software developed by the Swedish National Road Authority was introduced at MnDOT's Traffic Management Center. This system operated on a location database encompassing the interstate and trunk highway network in the Twin Cities Metropolitan Area.

***27** Adapted from "A Brief Description of the RBDS, the Radio Data Service" by David E.Knodel (taken off the Internet)*

***28** Rajendra. K., and Maki, R.E., The IVHS STRATEGY IN MICHIGAN, IVHS AMERICA, Washington, D.C., 1993.*

***29** Stehr R.E Carlson, G.C, Taylor. L.K., TRILOGY. IVHS AMERICA, Washington, D.C. 1994.*

Phase III represents the full-scale operational test currently taking place . This test was approved in June 1994, and is expected to be completed by the end of 1997.

Project Partners

This project is being conducted as a private/public partnership. Partners of these projects include the following:

- the Minneapolis Public School System radio station KBEM;
- Delco Electronics;
- AB Volvo Technological Development;
- Ford Motor Company;
- Indikta Display Systems LTD; and
- the University of Minnesota Human Factors Research Laboratory;
- Federal Highway Administration.

What made these partnerships attractive for RBDS-TMC equipment vendors was that the Minnesota location code was developed in accordance with the ITIS standard and guidelines established in Europe. For the pilot project, Ford donated three Ford Crown Victoria's while Indikta, based in the United Kingdom, donated two smart receivers for the project. Delco agreed to manufacture ten prototype smart receivers for a fixed dollar amount, much less than the development costs associated with the product.

AB Volvo is a Swedish auto manufacturer, whose Technological Development division has been active in ITS since 1986 as part of many European and US programs. In 1986, Volvo launched the first commercial RBDS unit, and in 1993, implemented in-vehicle devices in the Twin Cities for the Trilogy pilot test. For the operational test Volvo is supplying 135 RBDS-TMC receiving, processing, and output devices with the following capabilities:

- Graphics display - primary source of information delivery;
- GPS - icon to show the current location of the vehicle;
- automatic search for TMC frequencies;
- message filtering by area, message type, and /or message urgency, with filter settings remaining in memory if unit is switched off;

- 50 map frames for visual display of information, with a map zooming and panning feature;
- remote control operation for safer use while vehicle is in motion.

Indikta, based in the United Kingdom, is involved in advanced traffic information receiving and display systems. For the entire operational test, Indikta is supplying 75 RBDS-TMC receiving , processing, and output devices with the following features:

- Speech synthesis - primary source of information delivery;
- Text display pod - secondary source of information delivery;
- Information Filters - based upon geographic location and message type;
- Separate components - FM receiver, decoder and speaker. The devices will utilize a trunk-mounted CD-ROM for storage of data.

The Human Factors Research Laboratory was under contract to assess the safety, performance, and user friendliness of the various smart receivers used in the project. Its staff was also responsible for operational issues, designing user log sheets, questionnaires, and training project participants.

The FHWA's role in the Trilogy project is to provide overall direction as well as significant capital investment. This will ensure that Trilogy remains consistent with Federal Policies, procedures, and goals. FHWA's active participation will provide the means for technology and information transfer to and from other ITS activities throughout the nation.

Project Objectives

These are the objectives of the Trilogy Project:

- To create the procedures by which traffic data will be processed and distributed to motorists.
- To demonstrate the viability of area-wide broadcast of digital traffic information.
- To assess the safety, performance, and user-friendliness of the various smart receivers.
- To influence individual travel decisions.
- To make the most efficient use of the existing road infrastructure.

- To determine technical feasibility of enhanced Trilogy system.
- To address legal issues involved in the deployment of the technology.

System Operation and Procedures

The operational test consists of the following:

- identification of highway incidents (congestion, accident, construction, etc.) by the Minnesota Department of Transportation (MnDOT) Traffic Management Center (TMC) in the Twin Cities Metropolitan Area.
- electronic relay of highway-condition information by TMC to an FM radio station
- transmission of highway-condition information in digital format from the radio station via subcarrier to the in-vehicle receiver devices. Two types of transmission/communications media will be tested: Radio Broadcast Data System - Traffic Message Channel (RBDS-TMC) and a high- speed FM Subsidiary Carrier Authorization (FM-SCA).
- receipt of digitized information by in-vehicle devices, and conversion to output format understandable to the vehicle driver. Two types of output (information delivery) will be tested - audio and visual/graphical. One device (Indikta Display systems) uses speech synthesis as the primary source of information delivery and a text-display pod as a secondary source. The other device (AB Volvo's Dynaguide) uses a graphics display as the primary source of information delivery, and text display (of message) as a secondary source. The graphic display includes a highway map (at varying scales) and icons showing location of driver's vehicle and highway incidents.

The Trilogy information flow consisted of three basic components:

- the Trilogy work station;
- the transmission system; and
- the smart receivers.

A brief description of how the system works follows.

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[30] *Trilogy Operation Test, EVALUATION PLAN, Prepared by HNTB Corporation TRW Inc. and K. T. Analytics, Inc., May 1995*

Within the Twin Cities Metropolitan Area, an advanced infrastructure for collecting and processing traffic information is already in place. The Traffic Management Center collects incident and traffic congestion information over 170 miles of freeway via 3000 loop detectors, 156 closed-circuit TV cameras, monitoring police radio frequencies, and contact with Highway Helpers. Highway construction, highway maintenance, weather, and special event information are also collected, processed, and distributed to interested parties.[31]

The RBDS-TMC messages are manually entered at the Trilogy work station. The message is composed of location code, offset, duration, event, and advisory information. After these elements are selected from the menus, the computer program codes the message and stores it in a dynamic database which maintains active RBDS-TMC messages.

The dynamic database serves as the link from the computer program to the communication system. The contents of the dynamic database are passed to the encoder in one-minute cycles and repeated three times per cycle. Communication between the work station and the encoder, located at the KBEM transmitter tower, takes place via modem and a dedicated telephone line. The encoder converts information into binary groups. The binary group information is processed into a data stream and broadcast continuously using the 57 KHz sideband of KBEM's transmitter.

The FM multiplex, shown in Figure 2, carries a number of signals[32] The base frequencies are defined 200 KHz apart. A pilot tone is broadcast at 19 KHz offset from the base frequency allowing a receiver to identify the other signals. The mono signal carrying the main audio program is carried between 0 and 15 KHz. The stereo effect, added by difference signals, is carried between 23 and 53 KHz. Left and right speaker output is created by adding to and subtracting from the mono signal. The location for RBDS is 57 KHz and was selected based upon the results of field trials.

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[31] ***TRILOGY Operational Test, Concept/Preliminary Design Document, FHWA/MnDOT, May 1995***

[32] ***TRILOGY Operational Test, Concept/Preliminary Design Document, FHWA/MnDOT, May 1995***

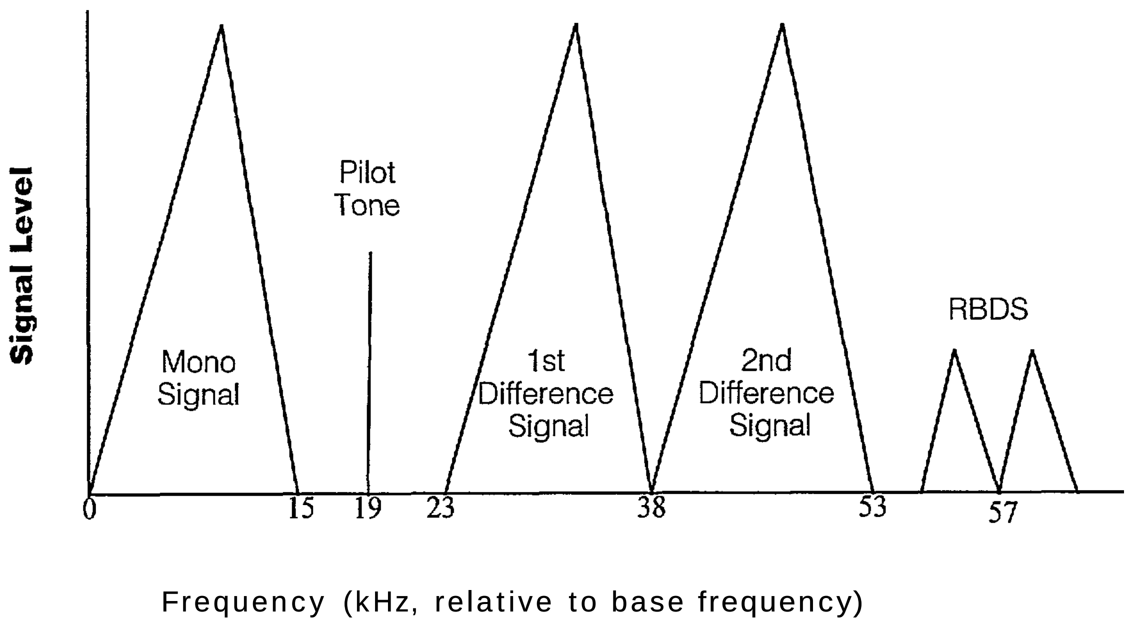

Figure 2: Spectrum of FM Station with RBDS

Smart receivers within the range of the transmitter decode the broadcast information and present it to the driver. RBDS-TMC smart receivers receive this transmitted information using a data rate of 1187.5 bps. Decoding of the data stream is done by referencing duplicate on board location, event, advice, duration, and offset databases. Presentation of the decoded information depends on the receiver capabilities, which range from simple text only displays to more advanced voice messages and map displays.

System Evaluation

The following aspects of this project are targeted for evaluation:

- the functionality and overall performance of the prototype receivers within different operating environments.
- assessment of driver interaction with the prototype system.
- required infrastructure and procedures, control room integration, operational issues

- refinements to system components (location coding, message list, interface program, and communication system), project participants feedback, and legal issues.

Findings

The Trilogy Project (Phases I and I i) has successfully demonstrated that digital information can be transmitted via the FM 88.5 sideband. As a consequence, the infrastructure is now in place to support this transmission. Procedures have also been established to provide accurate, reliable and timely information. The information can be effectively decoded in various formats (text, graphically, synthesized voice, or a combination of any of these methods). The resource requirements needed to support this type of initiative have been identified. The experience and feedback from the Phases I and II of the project highlighted the need for system component adjustment as summarized below:

- There was need for physical modifications of the TMC control room in order to integrate it with Trilogy. This was primarily aimed at enhancing the effectiveness of the control room operators.
- The test proved that the use of trained and dedicated operators is absolutely necessary for effective traffic message broadcasts. During the operational tests, a total of 866 REDS-TMC messages were broadcast and 358 incidents logged between January 3-29, 1994. Of the 660 incidents broadcast, 300 or 83.3% matched the incident log. The additional 360 incident related messages can be attributed to advisory messages alerting motorists of potentially hazardous situations (e.g., a stalled vehicle on the shoulder).
- There is need to refine system components such as location coding, the message list, the interface program, and the communication system. For example, there were complaints by project participants about the clarity of the messages due to inconsistent use of abbreviations. There were also complaints about message redundancies and inaccuracies.
- Problems with the prototype equipment were also addressed. Most of these problems related to the display of map and text information, the physical location of the display module in the vehicle, and the general performance of the equipment in severe weather conditions.

- The RBDS-TMC throughput is still low. The Trilogy project is capable of providing only thirty traffic information messages every fifteen seconds with the existing band width frequency. The advent of high speed FM-SCA, which will be implemented in the next phase of this project, will enable Trilogy to transmit ten times more traffic information messages every fifteen seconds.
- Since the RBDS technology is still a new medium for providing traffic information in the United States, sufficient public feedback is unavailable at this time due to the limited exposure and the small number of participants in the Trilogy project.
- Legal issues relating to the deployment of the technology were also addressed through the guidance of the Minnesota Attorney General. A major legal issue is the Minnesota law that prohibits television screens from being installed in vehicles at any point forward of the back of the driver's seat. However, this will not constitute an obstacle to the deployment of the technology since none of the receivers in the Trilogy Project are television receivers. Besides, an amendment to this statute has already been passed and signed by the Governor in 1993. This amendment allowed exception to be made for video screens installed as part of ITS applications.

The Trilogy Phase III Project

Following the success of the Trilogy Project Phases I and II, a proposal for a larger operational test of Trilogy has been developed by MnDOT in response to the Federal Request for Proposals. The experience gained in Phases I and II, is now being utilized in the Phase III operational test that is currently taking place.

The two types of in-vehicle receiver/decoder devices that are being used in the current Phase are being supplied by AB Volvo and Indikta Display Systems. The current market value of these devices in the United States is yet to be determined. The best measure of the price of these devices can only be obtained directly from the manufacturers.

According to the evaluations from one of the Trilogy project managers,[33] the possibility of integrating the decoders with a regular FM car radio is possible, although it is not necessarily the best solution for the end user. This is because of a limitation observed in the pilot project when the decoders were integrated with a single component FM car radio. This limitation forces the listener to remain tuned to one station the entire time in order to pick up the RBDS-TMC signal.

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[33] *Interview with Gary Hallgren TRILOGY Project Manager, MnDOT*

This means, in essence, that either every radio station would need to broadcast RBDS-TMC or a car radio would need two separate tuners if the listener wanted to change to another station while still tuned to the station that carries the RBDS-TMC signal.

It was also learned that at this point in time, there is not any work being done to standardize the receiver/decoder devices. It is perceived that any government imposed specifications or standardization at this time could limit competition and technological advances among manufacturers to develop and create better devices. The primary concern of the operators at this stage of the system evolution is to standardize the delivery and content of RBDS-TMC in order to ensure that the information broadcast is defined the same everywhere.

MnDOT is currently engaged in three operational tests that incorporate a variety of traffic information mediums. The Trilogy project utilizes RBDS-TMC with two types of decoder devices. The Genesis project uses pager frequency and a multi-function pager to broadcast and receive traffic information. Travelink provides transit and traffic information via video kiosks by direct phone line connection. However, Trilogy is the only project where the primary function is to provide real time in-vehicle traffic information.

APPLICATION OF THE RDS-TMC IN THE I-95 CORRIDOR

The I-95 Northeast Corridor, from Virginia to Maine, represents the center of the nation's financial, business, and political activity. It contains four of the nation's ten largest urban centers with a population of over 50 million people, 20 percent of the total US population. It is among the nation's most congested highway and travel corridors. The I-95 corridor actually covers a broad geographic area in the Northeast and firm boundaries have not been established since users of the Corridor's transportation system may come from beyond the Northeast. The Corridor is highly multimodal, with transportation provided by 14 state and city DOT's, 12 toll authorities, AMTRAK, several freight railroads, intercity buses, several major airlines and numerous public and private transportation suppliers. The USDOT formally designated the I-95 Northeast Corridor as a Priority Corridor on March 29, 1993.

The I-95 Corridor Coalition, a unique combination of state, toll, transit, and other transportation agencies, will enable the testing and evaluation of a wide number of ITS services along the I-95 Corridor. Through the use of advanced technology and increased interagency communications, the Coalition will work to coordinate transportation across jurisdictional lines and improve movement of people and goods in the Corridor.

Project 9, Coordinated VMS/HAR Strategies, was commissioned to provide the I-95 Corridor Coalition with a structure and deployment strategy for the overall coordination of VMS/HAR devices in the Corridor. Through a consistent pattern of use, VMS/HAR would provide motorists in the Corridor with real-time, continuous, and consistent information on incidents of Corridor significance. In addition, gaps within the existing system were identified and a phased implementation plan for installing new devices to complete the VMS/HAR network was developed. Through Project 9, VMS/HAR will become the primary traffic information dissemination system in the I-95 Corridor.

Highway Advisory Radio

While VMS/HAR are expected to meet the information dissemination needs of the I-95 Corridor, there are inherent limitations in the use of HAR. The output of HAR, which operates on the AM band, as well as its range and quality is dependent on the grounding system, the terrain and surrounding obstacles. Further, the operation of HAR is subjected to strict regulations by the FCC including:

- The output field strength is limited to 10 watts.
- HAR is restricted to only available frequencies.
- HAR must not interfere with any commercial radio stations. Any interference must be eliminated by the HAR operator.

As a result, HAR broadcasts are subject to static interference and range limitations, and are not always clearly received by motorists. This problem is intensified in the urban areas where a proliferation of established commercial AM stations make it difficult for HAR to find available broadcasting frequencies.

Despite its limitations, HAR has operated quite successfully over the last 20 years. The problems with HAR broadcasts as discovered in Project 9 has less to do with the FCC limitations and more to do with the inappropriate use of HAR, for example, the failure to update messages or to remove outdated messages, and the failure to broadcast relevant information on a current traffic condition. As a result, HAR has lost credibility with the public. However, to its credit, HAR is fully owned and operated by government agencies who gather and disseminate information to the motorists with no third party requirements. All vehicles are generally equipped with AM radios and therefore, other than obtaining an FCC license and setting up the station, there are no special partnerships required to bring this information to the motorists or no special outfitting of vehicles required for motorists to receive the HAR broadcast.

In the last two years, the HAR industry has seen the development of a computer controlled HAR system with the capability of controlling a number of HAR stations from one central computer. One such system is already installed in the Corridor (New Jersey Turnpike) and more “digital HAR” stations are expected to be installed and tested under the HAR Operational Test (Project 9A) now being conducted by the I-95 Northeast Consultants (I-95 NEC). Work is also in progress on providing a National Transportation Control/ITS Communication Protocol (NTCIP) -

based field implementation of digital HAR sites. The NTCIP is currently being developed and the I-95 Corridor Coalition is actively involved in this work.

RDS-TMC

RDS-TMC, described in this report, is a subcarrier on an existing FM band and does not require an open frequency to broadcast. RDS-TMC is not subjected to FCC regulations, has minimal interference on the existing FM station, and as a result of the generally superior quality of the FM band, is not expected to be affected by the inherent quality limitations of HAR. As a traffic information dissemination tool, RDS-TMC provides some basic capabilities that offer the potential of overcoming some of the limitations of HAR stations. These capabilities, some of which have been mentioned above, are summarized below.

- RDS-TMC is a subcarrier that utilizes the existing FM stations. This eliminates the problems of frequency availability and infrastructural costs.
- RDS-TMC in-vehicle decoder may not require the motorists to change stations/band in order to obtain traffic information as is required with HAR.
- RDS-TMC offers the user an optional self-tuning capability by automatically scanning and selecting the strongest signal carrying a program with traffic information.
- RDS-TMC has the capability of alerting the motorist to emergency information, even when the radio is off.
- RDS-TMC does not interfere with normal audio signals since it is an inaudible signal transmission.
- RDS-TMC can provide specific trip information for specific routes.
- RDS-TMC protocol is robust to the extent that its application transcends language differences and geographical boundaries through the Bearer Application Protocol (BAP) capability.

In addition, the equipment unique to the system operation is compact, typically taking less than twelve inches of standard equipment rack space. Installation is also simple, usually just a single cable from the subcarrier generator to an existing connection on the broadcast transmitter.[34]

[34] ***Small, E., Broadcast Subcarriers for IVHS: An Introduction.***

With advancements in computer and communications technology, it is also possible to interface RDS-TMC with other existing transportation management devices via the NTCIP. The NTCIP, when fully developed will constitute a complete communication protocol for integrating all of the various transportation management components that may be included in an ITS. The interface of RDS-TMC with other incident management devices, through a common protocol, could eliminate or minimize the need for data input operators at the Traffic Operations Center (TOC).

RDS-TMC is not without its problems. In Europe, where the development of RDS-TMC is well ahead of the United States, there is still no full scale deployment of RDS-TMC even after numerous projects have successfully demonstrated the capabilities of RDS-TMC as a traffic management tool. Largely, the problems are institutional rather than technological. The technology for deploying RDS-TMC is available, however, unlike HAR, there are aspects of providing this service that goes beyond the traditional boundaries of information dissemination by government agencies. Perhaps the biggest impediment to the deployment of RDS-TMC is the unresolved public/private partnership issues.

In-Vehicle Units

In order to receive RDS-TMC, vehicles must be fitted with special decoders. Private developers have invested a great deal of research time in developing these decoders and would expect to see some return on their investment. However, the data collection and dissemination network required to provide traffic information over the RDS-TMC must be established for these decoders to become marketable. In other words, real-time, consistent and accurate traffic information must be available in the l-95 Corridor before special decoders can be deployed. Consequently, a substantial investment of both time and money is required either to instrument the l-95 Corridor or to obtain the information from private sources.

In addition, car manufacturers will require sufficient time to incorporate these decoders into their vehicles. Since car models are generally designed two years in advance, and the decoder manufacturers may be required to modify their design to meet car manufacturer specifications, sufficient time must be allocated for the incorporation of these decoders into the car manufacturing process. At present, there is no indication that RDS-TMC decoders will be provided as standard issue on new vehicles or as an upgrade for older vehicles. Further, there is no indication that car manufacturers in the US will support the installation of RDS-TMC decoders in their vehicles. Therefore, the task of outfitting vehicles in the I-95 northeast corridor with in-vehicle decoders may not be realizable in the near future.

At issue also is who will be required to pay for these in-vehicle units. It is not certain that motorists will want to pay for a unit that will provide them with information that they receive for free from many FM and AM radio stations. Even though the traffic information provided by the RDS-TMC will be more extensive and current than the information available on regular FM/AM stations, motorists have grown become dependent on the traffic information services provided by these stations, It will, therefore, be a hard sell to convince motorists that purchasing these units will enhance traffic information service. At the same time, it is highly unlikely that car manufacturers will want to absorb the cost of outfitting vehicles with these decoders. Therefore, the issue of who will be required to bear the cost of outfitting vehicles with the in-vehicle decoders must be resolved before the I-95 Corridor Coalition can move forward with the deployment of RDS-TMC.

In-vehicle developers are ready to deploy their units. However, the lack of information to feed these in-vehicle decoders can be a serious drawback. Further, decoders must be accepted by car manufacturers, deployment of these decoders must be scheduled into the car manufacturing process, and the responsibility for the cost of these units must be resolved. In the US, the general acceptance of in-vehicle devices still needs to be determined. Without resolution of these issues, the deployment of RDS-TMC in the I-95 Corridor will likely face the same pitfalls that are now being experienced by Europe in its efforts to fully deploy its RDS-TMC program.

FM Stations

The successful deployment of RDS-TMC also requires the cooperation of the FM broadcasters. Unlike HAR where a government agency can apply for an open frequency, set up the station, and commence broadcasting, RDS-TMC is relayed as a sub-carrier on an existing FM channel. Therefore, the FM stations must buy into the idea of RDS-TMC. In Europe, many FM stations were not overcome by the technical challenge but were instead concerned about?

- Programming overload,
- Upsetting their listeners, and

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[35] ***Nuffal. Ian. RDS-TMC, 'Will Europe get if together.?', Traffic Technology, Autumn 1995***

- Getting income from their involvement.

The reaction of FM stations in the I-95 Corridor can be expected to be pretty much the same with the third issue, profitability of the partnership, being the most prominent. It is evident from the concerns of the European FM broadcasters that there is no easy answer to this issue. From all appearances, FM broadcasters are obviously concerned about public acceptance, but once public acceptance is gained, the issue will shift once again to who should bear the cost of providing the information. What is clear though, is that without the involvement of the FM broadcasters in this process, RDS-TMC cannot be successfully deployed in the Corridor.

While the use of a dedicated channel parallel to normal FM broadcasts produces advantages over HAR, RDS-TMC does have certain limitations inherent with the use of the FM signal:

- It has a low data transfer rate, and
- Its coverage is limited to only those areas covered by FM broadcast stations.

It will not be immediately possible to develop a comprehensive FM network in the I-95 Corridor to carry RDS-TMC. FM stations are generally concentrated in the metropolitan areas and their distribution becomes sparser as one moves away from the metropolitan areas. Consequently, without a comprehensive FM network, the I-95 Corridor is not prepared for a full scale deployment of RDS-TMC across the entire corridor.

Location Coding

Location coding contains information on geographic locations, highway names, route numbers, etc. Over time, new sections of highways are added or closed. As this happens, the location code must be updated. However, the mechanism for updating the code sets is not yet available. Another related issue involves the monitoring and coordination of the status of the roadway network throughout the Corridor in order to obtain the information required to update the location codes. The responsibility for managing this information and updating the location codes in the I-95 Corridor must be assigned. Such a task would appear to fall within the scope of the Corridor Clearinghouse, but the structure of the clearinghouse is still to be defined.

Lessons from the European Experience

The conflict created by public/private partnerships in the implementation of RDS-TMC is very evident in Europe. The private partnerships involved in the development of the RDS-TMC have invested a great deal of research time and are expecting some return on their investment. However, the question of who should pay for providing the information is a problem that operators in Europe are forced to grapple with as they race to implement RDS-TMC on a large scale. The governments of Sweden and Germany have undertaken the burden of providing traffic information via RDS-TMC free of charge to the public.[36] However, there are still some unresolved issues.

The Swedish National Road Authority (SNRA) has established contracts with other parties, covering the quality and type of information and the responsibilities of the broadcasting companies, to provide the information to the public over RDS-TMC.[37] Despite this achievement however, Sweden has not ruled out the possibility of implementing a fee for the service. The German effort, although moving ahead (a national implementation date of January 1, 1996 has been set) is constrained by German legislation which requires that traffic information should be provided free of cost. The situation in Europe is ably summarized by Nuttal[38] who observes that while all the components for the successful implementation of a European RDS-TMC are available, the partnerships demanded by RDS-TMC, because they cross the traditional public and private sector boundaries, are absent in many areas of Europe. Like Europe, the I-95 Corridor Coalition must resolve the issues associated with public/private partnerships before proceeding to implement RDS-TMC in the I-95 corridor.

Conclusion

A major drawback of RDS-TMC is that the technology is still in its infancy in the United States, and substantial field tests are still required to address operational and institutional problems. However, many successful projects in Europe have demonstrated the applicability of RDS-TMC and its infancy in the US should not preclude its consideration as an information dissemination tool in the I-95 Corridor. Based on the above discussion, it is believed that the opportunity exists for the use of HAR and RDS-TMC in tandem in the I-95 Corridor. In the metropolitan areas,

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36 Nuttal, Ian. RDS-TMC, 'Will Europe get if together.?" Traffic Technology, Autumn 1995.

37 Nuttal. Ian

38 RDS-TMC, "Will Europe get it together.?" Traffic Technology, Autumn 1995

where the unavailability of open AM frequencies already present a problem to HAR stations, the availability of existing FM stations which can carry the RDS-TMC signal favors the use of RDS-TMC. However, since there are no plans to commence outfitting vehicles in the l-95 Corridor with RDS-TMC decoders in the near future and with the public/private partnership issues still needing to be addressed, the actual implementation of RDS-TMC in the metropolitan sections of the l-95 Corridor cannot be seen as a short-term goal.

In moving away from the metropolitan areas, frequencies on the AM band begin to open up, making locations outside the metropolitan areas suitable to HAR. Also, it will be difficult initially to establish a comprehensive FM network across the Corridor to carry RDS-TMC, and as a result of its dependence on the FM signal, RDS-TMC will not present a viable option without such an established FM network. Therefore, not only is HAR suitable for use outside the metropolitan areas but until RDS-TMC is established as an information dissemination tool in the Corridor, HAR must remain one of the primary devices for disseminating information to Corridor motorists.

RDS has also been shown to be effective in transmitting messages to a VMS.[39] This reduces the need for the installation of underground cables and the associated construction costs, and also simplifies the location of remote signs. In addition, the messages to the VMS can also be transmitted to an in-vehicle decoder. Remote signposting, as it is referred to, has been successfully used in Chambety (France) to monitor 2,200 street parking spaces and two parking lots (1,200 spaces). The system is used to provide motorists with information on available parking spaces. The system was installed at a cost of US$ 320,000 and has been in operation since early 1993. In the Corridor, remote signposting can be used to transmit messages to remotely located VMSs.

The combined use of HAR, RDS-TMC and VMS in the l-95 Corridor, can provide motorists with a comprehensive information dissemination system that will give them real-time, continuous, and consistent information on incidents of Corridor significance throughout their journey. However, RDS-TMC is not immediately available for implementation in the Corridor. In addition to the institutional issues which must be resolved, the full-scale deployment of RDS-TMC in the US awaits the results of the Trilogy project in Minnesota which will essentially shape the direction of the technology in the US. Even if the Minnesota project is successful, it is still difficult to estimate a time frame for full-scale deployment of RDS-TMC in the US. In Europe, where RDS-TMC was

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***39** RDS: A Revolutionary Transmission System. D.E.P.I. Electronique.*

first discussed in 1974[40] and its success was proven in numerous projects, RDS-TMC has not been fully implemented, largely because of some of the institutional issues identified above. While the technology presents many advantages over HAR, particularly in the metropolitan areas, there are drawbacks in its development in the US that will delay its application in the I-95 Corridor.

More importantly, if the I-95 Corridor Coalition has any intention of implementing RDS-TMC in the corridor, it must begin by examining the institutional issues. At the heart of the matter, is who will bear the costs for the service. For the system to be successful, there must be in-vehicle decoders, developed at a cost. Information to these in-vehicle decoders must come from instrumented highways, which carry an inherent cost. The information must then be relayed by FM broadcasters who, like their European counterparts can be expected to express concern about the financial rewards for their service as well as the response of their listeners.

It is clear that the RDS-TMC system cannot be implemented without a successful public/private partnership. Recognizing that, the I-95 Corridor Coalition must move to resolve the issue of who will pay for the service once it is ready for implementation. Of equal concern is the public acceptance of RDS-TMC in the I-95 Corridor. In considering the implementation of RDS-TMC, the I-95 Corridor Coalition must give serious thought to the following:

- Full instrumentation will be needed on all main highways and alternate routes to provide reliable and real-time traffic information to the in-vehicle decoders.
- FHWA is heavily invested in the MnDOT Trilogy project and may not support another RDS-TMC project until the results of the Trilogy project are available.
- Developing a comprehensive network of FM stations across the I-95 Corridor to carry RDS-TMC will take time. Therefore, initially, RDS-TMC cannot be available for the whole corridor and must be used in tandem with other information dissemination devices.
- FM broadcasters must be involved in RDS-TMC from the beginning. At issue is how to make RDS-TMC profitable to the broadcasters without upsetting their listenership.
- The full participation of vehicle manufacturers must be enlisted to ensure their willingness to install the in-vehicle decoders.

[40] *Nuttal, Ian RDS-TMC, 'Will Europe get it together.?', Traffic Technology, Autumn 1995*

- The I-95 Corridor Coalition cannot provide the RDS-TMC service on its own. Private partnerships are required to bring the service to motorists and there are obvious associated costs. A clear decision/policy is required on who will pay to cover those associated costs.

Without thorough consideration of these factors and definitive answers to the implied issues, the I-95 Northeast Corridor will not be ready for a full scale implementation of RDS-TMC. However, some initial answers to these issues can be obtained through a pilot project.

Feasibility Study of RDS-TMC Implementation in the I-95 Corridor

The implementation of RDS-TMC promises to be a viable option for the enhancement of the traffic management system in the I-95 Corridor. While the results of the operational tests from the MnDOT's Trilogy project are being awaited, it is in the best interest of the Coalition to begin now to investigate the feasibility of implementing this new technology in the Corridor. A feasibility study can reveal possible peculiar systemic advantages and disadvantages inherent in the full implementation of RDS-TMC technology within the Corridor.

The next logical step, therefore, will be to undertake a feasibility study specifically geared towards the implementation of the RDS-TMC technology in the Corridor. A feasibility study is, therefore, proposed to evaluate the current traffic management structure with a view to implementing RDS-TMC technology on a small scale within the Corridor. The study will address institutional issues such as:

- The distribution of FM stations in I-95 Corridor.
- Programming structure .
- Responsiveness of the FM station operators.
- Responsiveness of the government traffic agencies.
- Roles the governments are willing to play.
- Responsiveness of operators and citizens.
- Responsiveness of car manufacturers.
- Legal issues.
- Public/Private partnership participation.
- The scale of the pilot project.

- The cost evaluation of the pilot project.
- Implementation and Evaluation of a Pilot Project

The preliminary requirement will be to evaluate the existing traffic information infrastructure within the Corridor. This means taking an inventory of the infrastructure for collecting and processing traffic information. These issues, however, are already being addressed by the I-95 Corridor Coalition Studies.

Distribution of FM Stations

An inventory of FM stations and their geographic distribution in the Corridor which will evaluate the extent of their transmission coverage.

Programming Structure

The programming structure of the stations will be evaluated so as to determine how the RDS traffic information programming can fit in.

Responsiveness of the FM Station Operators

The input of the FM station operators will be sought regarding the technical and financial implications of adapting the RDS technology to the regular FM programming.

Responsiveness of the Government Traffic Agencies

A determination of the roles that the various government agencies are willing to play in the realization of the technology in the Corridor.

Responsiveness of Operators and Citizens

Evaluation of the public response and reactions to the implementation of the RDS-TMC' technology, and feedback from various operators with an interest the RDS-TMC technology.

Responsiveness of Car Manufacturers

A determination of the willingness of car manufacturers to install RDS-TMC in-vehicle decoders.

Legal Issues

Identification of possible legal issues that may arise following the implementation of the technology. A specific examination of how the operational requirements of the technology will impact laws and policies of various states and agencies that make up the Corridor. In the same token, it will examine how the RDS-TMC operation will affect individual rights and preferences.

Public/Private Partnership participation

The identification of public/private partnerships that have the capability and interest to participate in a pilot project and the roles that each partnership is willing to play in the project.

Scale and staging requirements

The study will determine the most feasible scale and implementation procedures to be adopted for the pilot project.

Cost Evaluation of the Pilot Project

With the full participation of the public/private partnerships, a cost evaluation of a pilot project will be conducted.

The Scale of the Pilot Project

A determination of the magnitude of the pilot project:

- Extent of the test area,
- Number of FM stations,
- Number of vehicles to be fitted with in-vehicle decoders,
- Controlling TOC.

Implementation and Evaluation of a Pilot Project

With the identification of project requirements and level of partnership participation, the next step will be to define the project goals and operational guidelines. The final step will then be to implement and evaluate a pilot project.

APPENDIX 1

SUMMARY OF POTENTIAL BENEFITS AND LIMITATIONS OF RDS-TMC

Potential Benefits	Possible Limitations
• Utilizes the existing FM radio stations.	• More extensive operational testing still required before the system can be fully implemented.
• Relatively low operational and installation cost.	• The requirement that all vehicles be outfitted with the decoders is not realizable in the immediate future.
• Inaudible data transmission ensures non-interference with audio programs.	• Low data rate.
• Robust Protocol is language and Bearer-application independent and transcends geographical and national boundaries.	• Limited Geographic coverage.
• Provides specific trip information for specific routes.	• Coverage limited to only those areas covered by FM broadcast stations.
• System can be integrated with the existing incident management systems.	• One-way communication capability.
• Selective, and self-scanning in-vehicle decoders at affordable price.	
• The problem of low data rate may be ameliorated by using the Traffic Message Channel (TMC) feature. This feature is capable of multiplexing many RDS channels on various radio stations, each of which may be specific to a geographic region. This makes for more efficient utilization of the limited data capacity of the individual RDS channels.	

APPENDIX II

LIST OF ACRONYMS

AM	Amplitude Modulation
ARI	Autofahrer Rundfunk Information System (from W. Germany)
ATT	Advanced Transport Telematics
BAP/BIF	Bearer Application Protocol/Bearer Independent Format
BAST	Blaupunkt and the West German Ministry of Transportation
bps	bits per second
CRC	Castle Rock Consultants
DDIS	Dynamic Driver Information Systems
D.I.R.E.C.T	Driver Information Radio utilizing Experimental Communication Technologies
DRIVE	Dedicated Road Infrastructure for Vehicle Safety in Europe
DOT	Department of Transportation
EBU	European Broadcasting Union
FCC	Federal Communication Commission
FM	Frequency Modulation
FM-SCA	High speed FM Subsidiary Carrier Authorization
HAR	Highway Advisory Radio
INTERCHANGE	European project on RDS international data exchange standard
ITS	Intelligent Transportation System
ITIS	International Traveler Information Interchange Standard
MnDOT	Minnesota Department of Transportation
RBDS	Radio Broadcast Data Standard
RDS	Radio Data Systems
RDS-ALERT	Advice and Problem Location for European Road Traffic
R&D	Research and Development
RVI	Dutch Implementation project on RDS-TMC
SNRA	Swedish National Road Authority
TMC	Traffic Message Channel
TSM	Transportation System Management
TRILOGY	MnDOT's Pilot project on RDS-TMC
USDOT	US Department of Transportation
VHF	Very High Frequency
VMS	Variable Message Sign